RESEARCH DEPARTMENT

THE VARIATION IN THE VISIBILITY OF INTERFERENCE OVER THE GREY SCALE OF A TELEVISION PICTURE

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SUMMARY

Subjective measurements have been made in order to establish the relative visibility, at different points on the grey scale, of interference superimposed on a television picture. Results are compared and contrasted for a number of distinct types of interfering signal.

1. INTRODUCTION

It is sometimes required to know the relative subjective visibility of noise or other interference at different grey-levels* of a television picture, given the objective magnitude of the interference. A relationship of this type was recently established[1] for an interfering signal that produced a stationary, coherent pattern; a displayed test card had numerals superimposed, at a barely visible level of contrast, on the five plain squares of the step wedge. By measuring the values of contrast at which the numerals could just be identified it was possible to establish the relationship between the visibility of a pattern of this type and its mean grey-level.

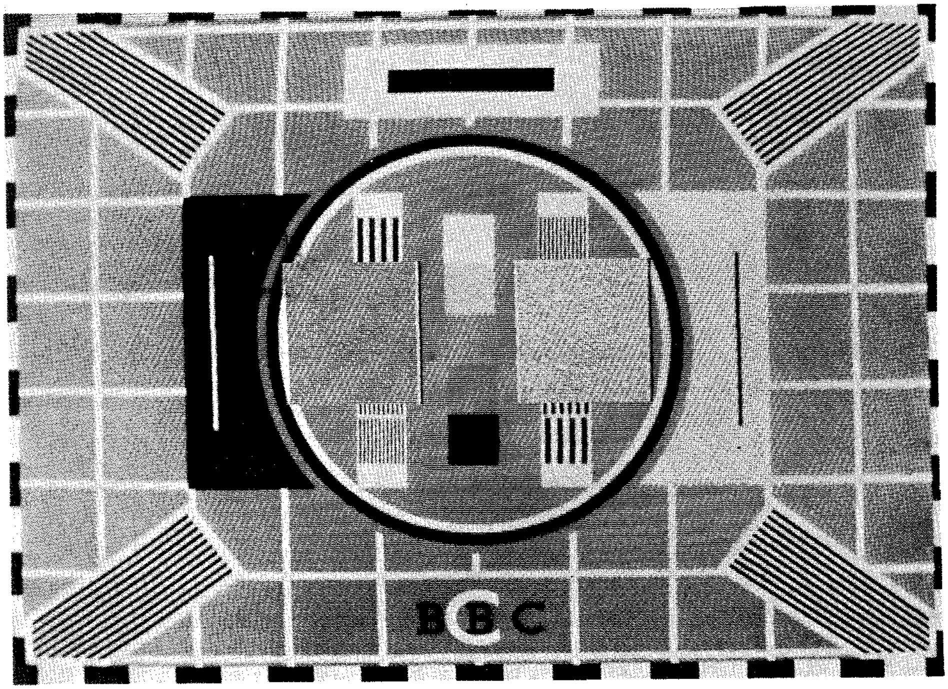
However, when attempts were made to apply this relationship to problems involving the visibility of random noise, discrepancies were found suggesting that the relationship was not unique, as had been assumed, but depended on the nature of the superimposed signal. This report describes an investigation of this dependence, in which the visibilities of several types of superimposed signal were measured as a function of grey level.

2. DESCRIPTION OF THE EXPERIMENTS

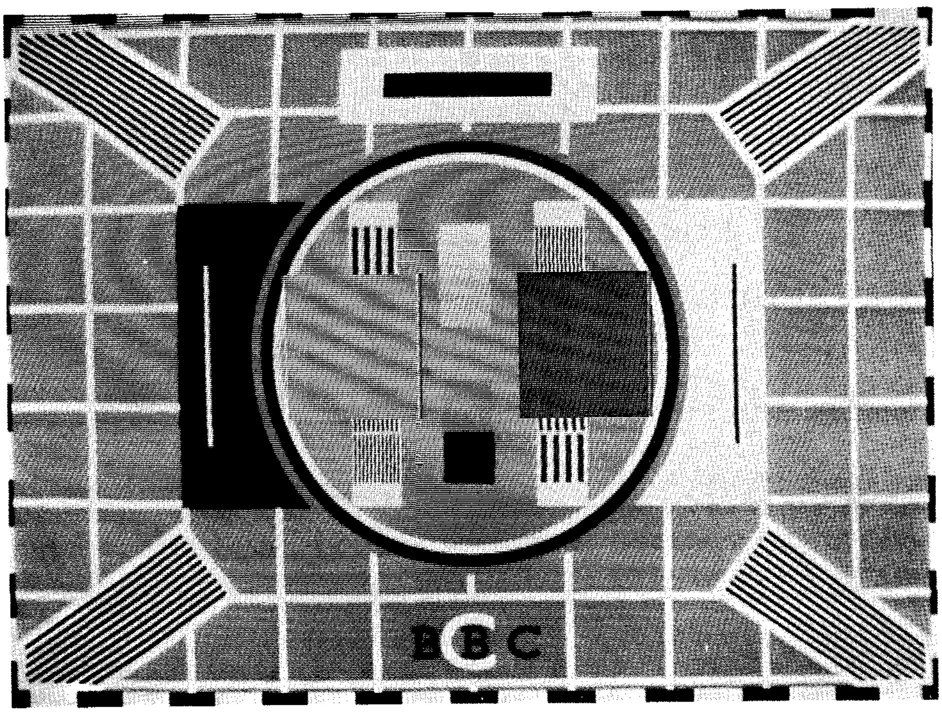
Fig. 1 shows two typical displays used in the experiments. Each consists of a normal test card into which two comparatively small test areas have been electronically "inlaid"; consequently the observer's eye was maintained in a state of adaptation appropriate to the viewing of television pictures.

The test procedure will be described for the case illustrated in Fig. 1(a), in which random noise was displayed in both squares. One of the team of seven observers that took part in the tests sat in front of a 21 in (53 cm) monitor, at a distance from the screen equal to five times the height of the displayed picture. The engineer supervising the test could control the mean grey-level of each square test-area and the amplitude of the noise waveform displayed in the left-hand square.

*The qualitative term 'grey level' is used here in order to describe the brightness of any part of a picture relative to the peak-white brightness.



(a)



(b)

Moiré patterns visible in these reproductions are due to the printing process and were not present in the original display

Fig. 1 - Forms of display used in the tests

(*a*) Random noise in test squares
(*b*) Coherent pattern in test squares

An attenuator controlling the amplitude of the noise waveform displayed in the right-hand square was operated by the observer, whose task was to adjust this attenuator until he judged the noise to be equally visible in the two squares.

For the purposes of this investigation it has been found convenient to describe grey levels in terms of a percentage scale of video voltage, having the voltage at blanking level as zero and that at peak white as 100 per cent. The quantity so defined will be referred to as the 'picture-signal level'. Throughout the test the mean picture-signal level within the left-hand square was maintained at 50 per cent, and the superimposed noise-voltage was maintained at a predetermined amplitude. The mean picture-signal level of the right-hand square was successively set to a number of values, and for each value the observer adjusted his attenuator, taking his own time to do so; the attenuator setting was then recorded by the supervising engineer. High and low values of picture-signal level were presented in a random sequence in order to minimize any tendency for the observer to be influenced by his previous decisions. Each test included a control comparison in which the mean picture-signal level was the same for the two squares, thus providing a check of equipment calibration. The contrast range of the display was eighty to one, bounded by brightnesses of 20 ft-L and 0·25 ft-L.

The relationship between brightness and picture-signal level for the particular monitor used is shown in Fig. 2. The setting of the brightness control was such that no scanning lines were visible in areas scanned at blanking level. The brightness of these areas was 0·25 ft-L, although the ambient lighting caused the screen to reflect a brightness of only 0·13 ft-L when the monitor was switched off; this discrepancy is similar to that encountered during the investigation described in Reference 1, and is thought to be due to flare in the tube face. The ambient lighting caused a brightness of 0·35 ft-L to be reflected from a white card held in front of the tube face. It was found necessary to restrict the picture size in order to prevent the illuminated part of the raster from extending beyond the edges of the screen, because excitation of the phosphor on the sides of the tube increased the brightness in dark parts of the picture, with consequent loss of contrast.

Three types of random-noise waveform were used in the tests, a low-pass filter being used in each case in order to restrict the bandwidth to 3 Mc/s.

(i) 'Flat' noise.

This was the output from a noise generator* designed by the B.B.C. Designs Department. It utilizes an illuminated photo-multiplier as its noise-generating element, and is designed to produce an output having a uniform energy-spectrum over the range of frequencies extending from 100 kc/s to higher than 3 Mc/s.

(ii) 'Triangular' noise.

This noise was derived from the flat noise by passing it through a circuit whose gain was proportional to frequency.

(iii) 'Receiver' noise.

This was the output of a vestigial-sideband television receiver fed with a c.w. signal at its vision-carrier frequency.

*Type GE4/501 P.

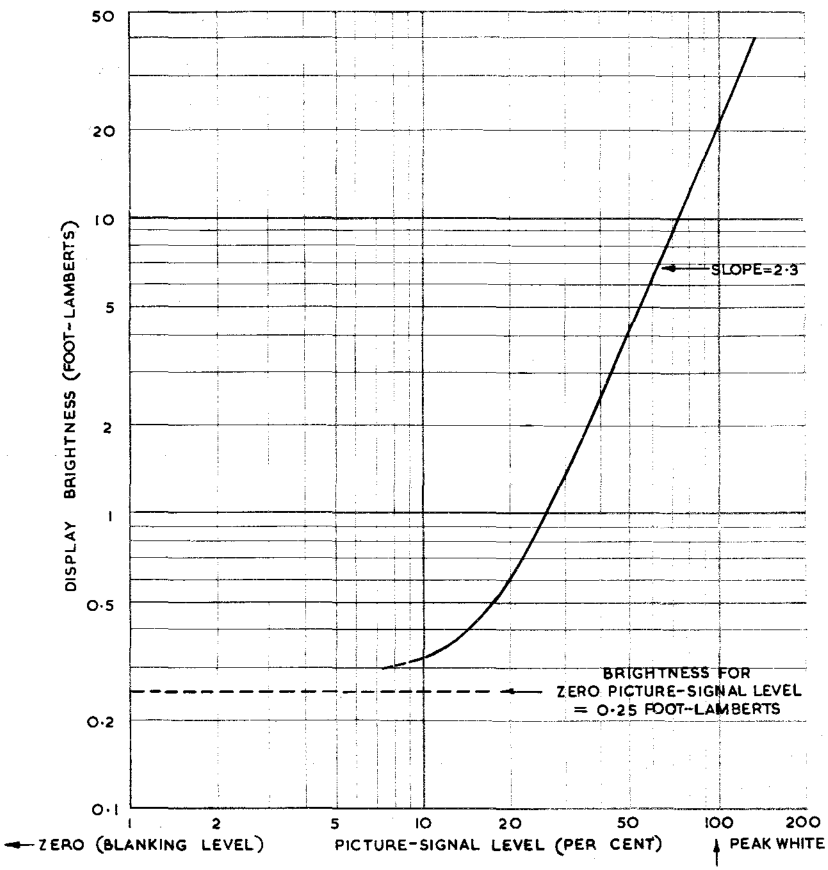


Fig. 2 - Contrast law of monitor used

The ratio between the maximum peak-to-peak value and the r.m.s. value was measured for each type of noise. The peak-to-peak value was measured by observing a waveform monitor, and the r.m.s. value was measured by means of a thermocouple; a sinusoidal waveform was used for mutual calibration of the two measuring instruments. For all three types of noise the ratio was measured as 18 dB.

All the tests involving noise were carried out at the same degree of visibility. The reference signal defining this visibility was flat noise superimposed on a mean picture-signal level of 50 per cent and having an r.m.s. value 35 dB below the black-to-white amplitude of the picture waveform; either this reference signal or a signal adjusted to have the same visibility was displayed in the left-hand square for all tests.

In addition to tests of the type already described, in which visibility was related to grey level for a particular type of noise, the investigation included tests to establish the relative visibilities of different forms of noise at identical values of grey level. A test of this type was carried out at an early stage of the investigation in order to determine whether there was any measurable difference in visibility between flat noise and receiver noise. Flat noise was displayed in the left-hand square and receiver noise in the right-hand square. The two

squares were maintained at a common value of mean picture-signal level which was successively set to be 10 per cent, 50 per cent, and 100 per cent. To maintain the noise in the left-hand square at the standard visibility its amplitude was appropriately adjusted for the tests at picture-signal levels of 10 per cent and 100 per cent. The result of this test established that there was no measurable difference in visibility between the two types of noise at any of these three grey levels, and receiver noise was not used in any further tests, it being assumed that the results for flat noise were also valid for receiver noise.

A further comparison established the difference in visibility between flat noise and triangular noise. This comparison, which was made with both squares at a mean picture-signal level of 50 per cent, showed that the r.m.s. value of triangular noise should be 6 dB higher than the reference value of flat noise in order to be equally visible. Thus in the subsequent measurement of the relationship between visibility and grey level for triangular noise, the reference signal consisted of triangular noise superimposed on a mean picture-signal level of 50 per cent and having an r.m.s. value 29 dB (35 dB − 6 dB) below the black-to-white amplitude of the picture waveform.

In the measurements involving stationary, coherent patterns two forms of test signal were used. The first of these produced a display of the form illustrated in Fig. 1(b), and consisted of a square wave having a fundamental frequency of about 250 kc/s, suitably locked to the line-scanning frequency. The bandwidth of this signal was limited to 3 Mc/s by means of a low-pass filter. The other form of test signal was a sine wave having a frequency of 2 Mc/s; this signal also was locked to the line-scanning frequency so that vertical stripes were displayed in the test squares. When these test signals were used, the peak-to-peak amplitude of the reference signal displayed in the left-hand square, at a mean picture-signal level of 50 per cent, was 1 per cent for the 250 kc/s waveform and 2½ per cent for the 2 Mc/s waveform. The respective visibilities of the patterns produced by these two reference signals were similar to each other and to that of the standard noise signal already specified.

3. RESULTS

Fig. 3 shows the results that were obtained for flat noise, triangular noise, and the two patterns just described. The abscissae represent values of the mean picture-signal level, and the ordinates represent, in decibels, the relative amplitudes of the test signal that were found to be necessary for the achievement of constant visibility. The vertical relationship between the curves has been chosen in order to show their similarities and differences; the absolute amplitudes represented by them may be derived from the arbitrary scale of decibels by referring to the table in the lower right-hand corner of the figure. Each curve represents the mean of results obtained from the team of seven observers, all of whom were engineers accustomed to making critical appraisal of television pictures. The standard deviation of individual results from the mean result had an average value of about 1 dB for mean picture-signal levels of 25 per cent or more, but increased to an average value of about 1½ dB for lower values of mean picture-signal level.

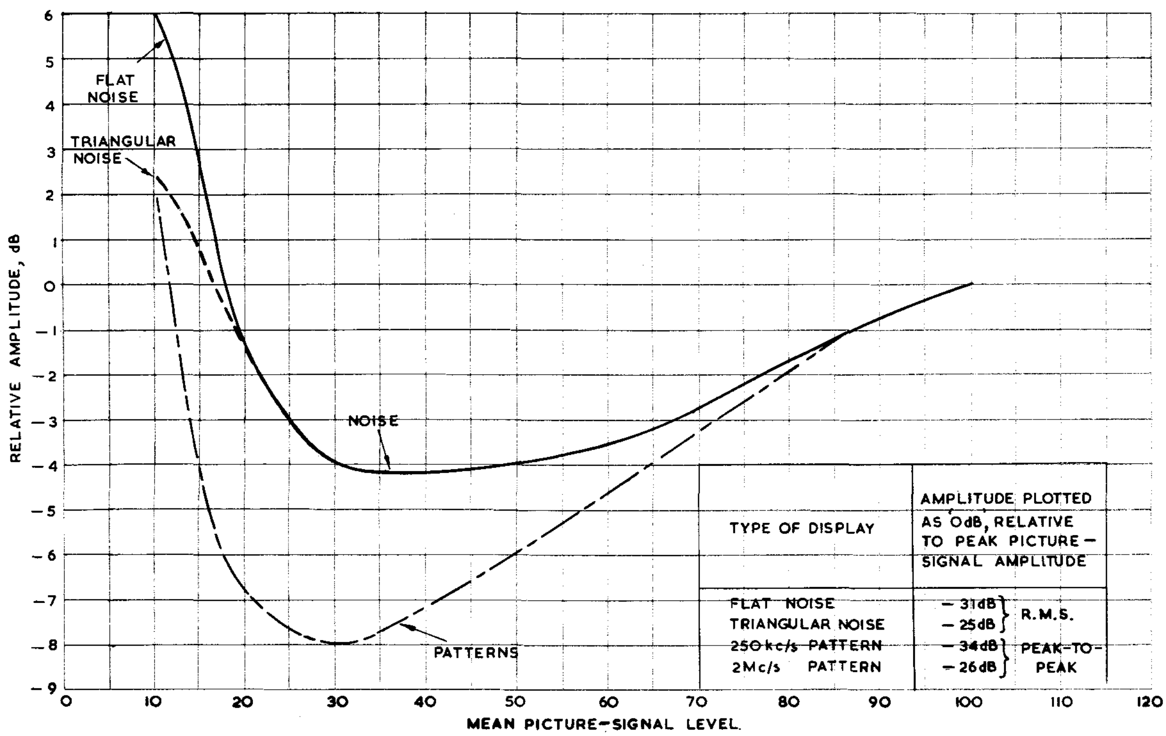


Fig. 3 - Amplitudes of interference producing a constant visibility, as a function of the mean grey-level of the background

It will be seen that a single curve has been drawn for the two patterns described, and that only at values of mean picture-signal level below 20 per cent is the curve for triangular noise shown as differing from the curve for flat noise. Where two curves have been assumed to be identical the approximation involves a maximum error of 1 dB and a mean error of about ½ dB.

The grey level at which flat noise is most visible has been measured, under threshold conditions of visibility, by Kilvington et al.[2] Maximum visibility was found to occur for a mean brightness equal to 8·6 per cent of the maximum brightness, which corresponds to a picture-signal level of 35 per cent in Fig. 3; this result is therefore in good agreement with the results of the present investigation.

A display of random noise differs from a stationary pattern in being incoherent in both space and time, and random-noise waveforms are also characterized by higher crest factors than those of sine waves and square waves. In an attempt to discover whether any one of these properties is primarily responsible for the difference in shape between the 'noise' and 'patterns' curves of Fig. 3, tests were carried out using waveforms that included only two of these three properties. A signal having a crest factor of about 6 dB was produced from the flat-noise signal

by peak-clipping. The results obtained with this test signal, when expressed in the form adopted in Fig. 3, defined a curve whose shape was very like that of the curve for flat noise, which had a crest factor of 12 dB; thus the value of the crest factor does not appear to be significant.

Another test signal was produced, by means of a television camera, from a transparency of enlarged photographic grain. This signal had a crest factor similar to that of random noise and produced a spatially incoherent display which, however, differed from that of random noise in being stationary.

When the results obtained with this test signal were expressed in the form adopted in Fig. 3, the curve they defined could be made to lie within ½ dB of the 'patterns' curve for values of the mean picture-signal level of up to 50 per cent. However, if this was done, the curves diverged for higher values of mean picture-signal level; that for the stationary pseudo-noise was then parallel to the 'noise' curve.

4. DISCUSSION OF RESULTS

When the results of the tests are expressed in the form shown in Fig. 3 they are applicable only to the particular monitor used, and to a particular setting of its brightness control. In Fig. 4 the results have been expressed in a more

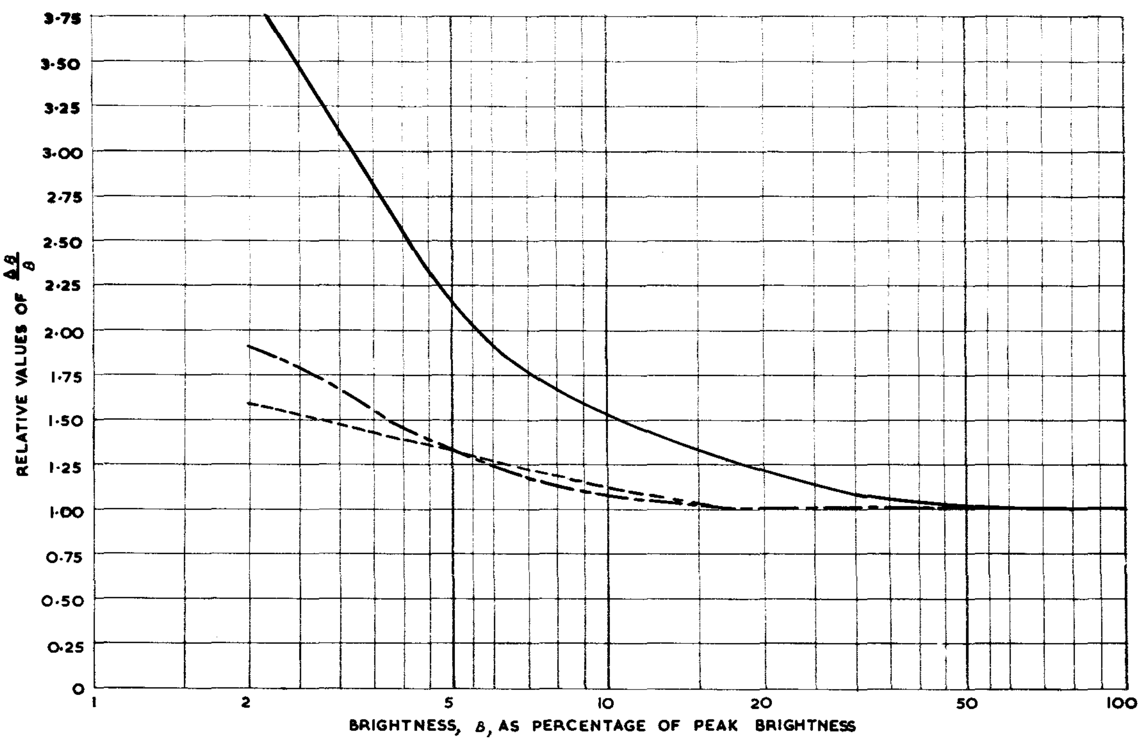


Fig. 4 - Variation with background grey-level of the fractional brightness-difference producing a constant visibility of interference

— — — — — Visibility of numerals (Ref. 1)
———— - ———— Stationary coherent patterns
—————— Random noise

generally applicable form by transforming the variables of Fig. 3; this has been done by making use of the relationship between the brightness of the monitor screen and the picture level, which is shown in Fig. 2. The abscissae of Fig. 3 have been transformed to values of mean brightness, and the ordinates to relative values of fractional brightness-change. Neither transformation is valid when the superimposed test-waveform contains very large excursions, and for this reason all the results measured at a mean picture-signal level of 10 per cent have been omitted from Fig. 4, as has the result for triangular noise at a mean picture-signal level of 15 per cent. The figure also includes a curve plotted from the results of the investigation into the visibility of numerals (Reference 1), and this curve may be seen to be in good agreement with the curve for stationary, coherent patterns.

All of the curves exhibit a horizontal portion at high values of mean brightness, indicating that the Weber-Fechner law is obeyed under these conditions; at lower levels of brightness there is a progressive increase in the fractional brightness-change required for the achievement of constant visibility. This conclusion is in general agreement with that reached by Billard,[3] who measured thresholds of visibility for patterns, under somewhat different experimental conditions.

It may be seen from Fig. 4 that the visibility of stationary, coherent patterns obeys the Weber-Fechner law for all values of brightness exceeding about 10 per cent of the maximum, but that it is only for values of brightness exceeding about 30 per cent of the maximum that the visibility of random noise varies in this way.

The 'patterns' curves of Figs. 3 and 4 have been found to be equally applicable to either of two stationary, coherent patterns, derived from video signals whose respective fundamental frequencies were in the ratio of eight to one; similarly, for brightnesses exceeding 3 per cent of the maximum, the 'noise' curves have been found to be applicable to the display corresponding to either of two waveforms, one of which was the time derivative of the other. It therefore seems unlikely that the general shape of the video spectrum above 100 kc/s affects the shape of the relationship between visibility and grey level. It would appear that at low grey-levels the 'patterns' curves are applicable to any stationary display, even if it is spatially incoherent, whereas at high grey-levels the 'noise' curves are applicable to any spatially incoherent display, even if it is stationary.

5. CONCLUSIONS

It has been found that, under conditions of visual adaptation appropriate to the viewing of television pictures, the function relating the visibility of random noise to its mean grey-level is markedly different from the corresponding function for stationary, coherent patterns. The difference is such that the departure from the Weber-Fechner law at low grey-levels is greater for noise than for patterns, and extends over a larger part of the grey scale.

6. REFERENCES

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2. Kilvington, T., Judd, D.L., and Meatyard, L.R., "An Investigation of the Visibility of Noise on Television Pictures", Post Office Radio Report No. 2289 (1954).

3. Billard, P., "Les Seuils Differentials de Luminance en Télévision", Acta Electronica, Vol. 2, Nos.1 and 2, p. 283, 1957-8 or Optica Acta, Vol. 5 No. Hors Série, p. 283, Jan. 1958.